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Low-load resistance training reduces injury incidence and burden, and improves the physical performance in youth soccer players

El entrenamiento de fuerza con cargas bajas reduce la incidencia y gravedad lesional, y mejora el rendimiento físico en futbolistas jóvenes

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Abstract

The inclusion of some specific strength training programs could be a key strategy to reinforce the injury prevention process. This study aimed to analyze the effects of a 12-week low-load resistance training program on injury incidence, burden, and physical fitness in semiprofessional youth soccer players. Twenty male players were randomly assigned to the experimental group (EG, n = 10 players), which performed a low-load resistance training program, or to the control group (CG, n = 10 players), which performed only their usual soccer training. Injury incidence and injury burden were registered during the intervention, as well as the physical fitness attributes: jumping, repeated sprint abilities (RSA), change of direction ability (CODA), linear sprints and isometric strength, at baseline and after the training program. A significant ($p < 0.05$) lower injury incidence was observed in EG (CG: 9.57 vs. EG: 0.00 injuries/1000 h of exposure) and a significant ($p < 0.001$) lower injury burden in the EG (CG: 317.83 vs. EG: 0.00 days of absence/1000 h of exposure). The ANCOVA model revealed significant between-group differences favoring the EG, showing significant higher improvements in all physical fitness attributes ($p < 0.001$–0.024). This study demonstrated the effectiveness of a low-load resistance training program in preventing injuries and improving physical condition in young soccer players.

Keywords: football; prevention; condition; injuries; power.

Resumen

La aplicación de programas de entrenamiento de fuerza podría ser una estrategia crucial para reforzar el proceso de prevención de lesiones en fútbol. El objetivo de este estudio fue analizar los efectos de un programa de entrenamiento de fuerza con cargas bajas de 12 semanas de duración sobre la incidencia lesional, el *burden*, y la condición física en futbolistas jóvenes semiprofesionales. Veinte jugadores fueron asignados aleatoriamente al grupo experimental (EG, n = 10 jugadores), que realizó un programa de entrenamiento de fuerza con cargas bajas, o al grupo control (CG, n = 10 jugadores), que realizó sólo su entrenamiento de fútbol habitual. Se registró la incidencia lesional y el *burden* durante la intervención, así como el rendimiento en diferentes pruebas: salto vertical, habilidad para repetir sprints (RSA), habilidad para cambiar de dirección (CODA), sprint en línea recta y fuerza isométrica, al inicio y después del programa de entrenamiento. Se observó menor incidencia de lesiones en el EG (CG: 9,57 vs. EG: 0,00 lesiones/1000 h de exposición) y un burden más bajo en el EG (CG: 317,83 vs. EG: 0,00 días de ausencia/1000 h de exposición) de forma significativa ($p < 0,001$). El modelo ANCOVA reveló diferencias significativas entre grupos a favor del EG, mostrando mejoras significativamente superiores en el rendimiento físico ($p < 0,001$-0,024). Este estudio demostró la efectividad de un programa de entrenamiento de fuerza con cargas bajas para prevenir lesiones y mejorar la condición física en jóvenes futbolistas.

Palabras clave: fútbol; prevención; condición; lesiones; potencia.

Introduction

Soccer is one of the most popular sports worldwide, with nearly 200 million participants (Longo, Loppini, Cavagnino, Maffulli, & Denaro, 2012). Participation in this team sport offers many health advantages, but due to its physically demanding nature, it also carries a higher risk of injury (Fuller, Junge, DeCelles, Donald, Jankelowitz, & Dvorak, 2010). These injuries may counter the positive effects of sports participation if an athlete is unable to play due to the injury (Martins, França, Sarmento, Henriques, Przednowek, Nascimiento et al., 2024). Being injured negatively affects players' mental state and dismishes the sporting performance of teams, as well as having a negative economic impact for clubs (Hägglund, Waldén, Magnusson, Kristenson, Bengtsson, & Ekstrand, 2013; Hurley, 2016). Consequently, soccer clubs have shown ongoing interest in having practical, interpretable and usable strength training models to support regular football training to reduce injuries (Kirkendall, & Dvorak, 2010). Clinically, the literature describes the lower extremities as the most affected by sports injuries (Hoffman, Dwyer, Tran, Clifton, & Gastin, 2019; Lee, Jeong, & Lee, 2020; Torrontegui, Gijon, Perez, Morales, & Luque-Suarez, 2020), particularly muscle injuries in the thigh, quadriceps and groin areas (Jones A, Jones G, Greig, Bower, Brown, Hind, & Francis, 2019; Krutsch, Memmel, Alt, Krutsch, Tröß, aus der Fünten, & Meyer, 2022). Scientific evidence has noted injury incidence ranging from 6.2 to 12.4 injuries per 1000 h of exposure, with severe injuries accounting approximately 12-18% of injuries in semiprofessional soccer players and being lower leg contusion and knee sprain the most common specific injury types (Baldjian, Mohrenberger, & Ciladi, 2022; Owoeye, Aiyegbusi, Fapojuwo, Badru, & Babalola, 2017). Considering that injuries is a real problem in modern soccer, it is crucial to adopt appropriate training methods to prevent injuries and increase player availability (Harper, Carling, & Kiely, 2019; Impellizzeri, McCall, Ward, Bornn, & Coutts, 2020).

Improving the physical fitness attributes of soccer players could enhance their participation during competition and mitigate the risk of suffer an injury during training and matches (Rossi, Pappalardo, Cintia, Iaia, Fernàndez, & Medina, 2018). The inclusion of some specific strength training programs could be a key strategy to reinforce the injury prevention process (Ekstrand, Spreco, Bengtsson, & Bahr, 2021; Gabbett & Domrow, 2007). Some investigations have highlighted the positive effects of resistance training in injury prevention (Olivares-Jabalera, Fílter, Dos'Santos, Afonso, Villa, Della, Morente, Soto, & Requena, 2021; (Pérez-Gómez, Adsuar, Alcaraz, & Vivas, 2022). Since one of the biomechanical risk factors includes inadequate strength and muscle control of core and hip stabilizers (Bakal, Hussain, Dzierzawski, Meyer, Dawson, & Olufase, 2024; Ribic, Hadzic, & Spudic, 2024), improving gluteus medius activation through resistance training appears to positively impact reducing knee valgus during landing after jumping actions (Lephart, Abt, Ferris, Sell, Nagai, Myers, & Irrgang, 2005; Myer, Ford, McLean, & Hewett, 2006). Furthermore, it has been observed that the activation level and strength of the gluteus medius during high-speed running showed a strong correlation with reducing hamstring injuries (Franettovich, Bonacci, Mendis, Christie, Rotstein, & Hides, 2017). Also, one study observed that a side-to-side average muscle activity asymmetry between the left and right hamstring muscles was activated during sprinting activities in soccer players (Pietraszewski, Gołaś, Matusiński, Mrzygłód, Mostowik, & Maszczyk, 2020). These findings suggest that the hamstring and gluteal muscles should be emphasized in the strength training of soccer players, improving physical performance and preventing injuries in soccer players.

Resistance training consist of applying effort to overcome resistance, which results in increased muscle fiber recruitment and stronger synchronization, ultimately enhancing neuromuscular control and leading to muscular growth (Ahern, Nicholson, O'Sullivan, & McVeigh, 2021). This improved coordination and muscle activation causes intermediate twitch fibers to act like fast twitch fibers, thereby reducing fatigue in the latter (Blazevich & Sharp, 2005; Plotkin, Coleman, Van Every, Maldonado, Oberlin, Israetel, Feather, Alto, Vigotsky, & Schoenfeld, 2021). Additionally, fast fibers are known to have lower stretching capacity, fatigue more easily, and possesshigher viscosity due to their morphological characteristics (Blazevich, Cannavan, Coleman, & Horne, 2007). Considering these improvements, there could be less muscle fatigue and a consequent reduction in the number of musculotendinous injuries (Timmins, Filopoulos, Nguyen, Giannakis, Ruddy, Hickey, Maniar, & Opar, 2021). Literature suggests that lower load resistance training [i.e., loads < 50% of one-repetition maximum (1RM)] can serve as an effective alternative to traditional higher load training (i.e., loads > 70% of 1RM) and, in many cases, can promote similar or even superior physiological adaptations (Weakley, Schoenfeld, Ljungberg, Halson, & Phillips, 2023). Although, other authors postulate that training with lighter loads may be detrimental for long term isokinetic strength in recreationally-trained athletes (Bello, Gillen, & Smith, 2024). Therefore, it could be relevant in young semi-professional soccer players to determine if lower loads of strength training can be effective in reducing injuries and improving physical performance.

Therefore, this study aimed to analyze the effects of a 12-week low-load resistance training program on injury incidence, injury burden, and physical fitness attributes in young semiprofessional soccer players. The hypothesis is that a low-load resistance-oriented training programs could ameliorate the injury patterns and the physical performance in semiprofessional soccer (Iodice, Trecroci, Dian, Proietti, Alberti, & Formenti, 2020; Lesinski, Prieske, Chaabene, & Granacher, 2021).

Methods and Materials

Participants

Twenty young semiprofessional male soccer players (age: 16.7 ± 0.1 years, height: 177.0 ± 7.0 cm, weight: 69.5 ± 7.7 kg and body mass index [BMI]: 22.1 ± 1.6 kg/m^2) voluntarily participated in this study. Players belonged to the same team and competed in the Tier 3: Highly Trained/National Level (McKay, Stellingwerff, Smith, Martin, Mujika, Goosey, Sheppard, & Burke, 2022). Soccer players were randomly assigned to an experimental group (EG, n = 10, age: 16.6 ± 0.7 years, height: 176.4 ± 6.0 cm, weight: 68.8 ± 7.0 kg, BMI: 22.1 ± 1.7 kg/m^2) who performed low-load resistance training in addition to their usual training, and to the control group (CG, n = 10, age: 16.8 ± 0.8 years, height: 178.0 ± 8.0 cm, weight: 70.2 ± 8.6 kg, BMI: 22.1 ± 1.7 kg/m^2) who did not perform additional specific low-load resistance training. The number of participants in each group was based on previous literature (Brull-Muria & Beltran-Garrido, 2021; Miyazaki & Fujii, 2022). In addition, there are usually no more than 22-23 field players in a team and to ensure that the training sessions are similar for all players, it is necessary to do it in the same team. The weekly training volume was four soccer-specific training sessions of approximately 75 min each (totaling 300 min) and one official match on a weekend. All players met the inclusion criteria ensuring a minimum of 80% of the low-load resistance training sessions (including both soccer and strength sessions) throughout the 12-week period and to be free of injuries the month preceding the investigation (Figure 1). The two goalkeepers were excluded from statistical analysis due to their special role in soccer practice, and the players who were injured at the beginning of the investigation were also excluded (n = 2). All participants were informed of the benefits, procedures and potential risks of the study and they gave their written informed consent to participate. The study was conducted in accordance with the Declaration of Helsinki (2013) and the protocol was approved by the ethics committee of the ***for blinded purposes*** (Code PI 22-2793 NO HCUV).

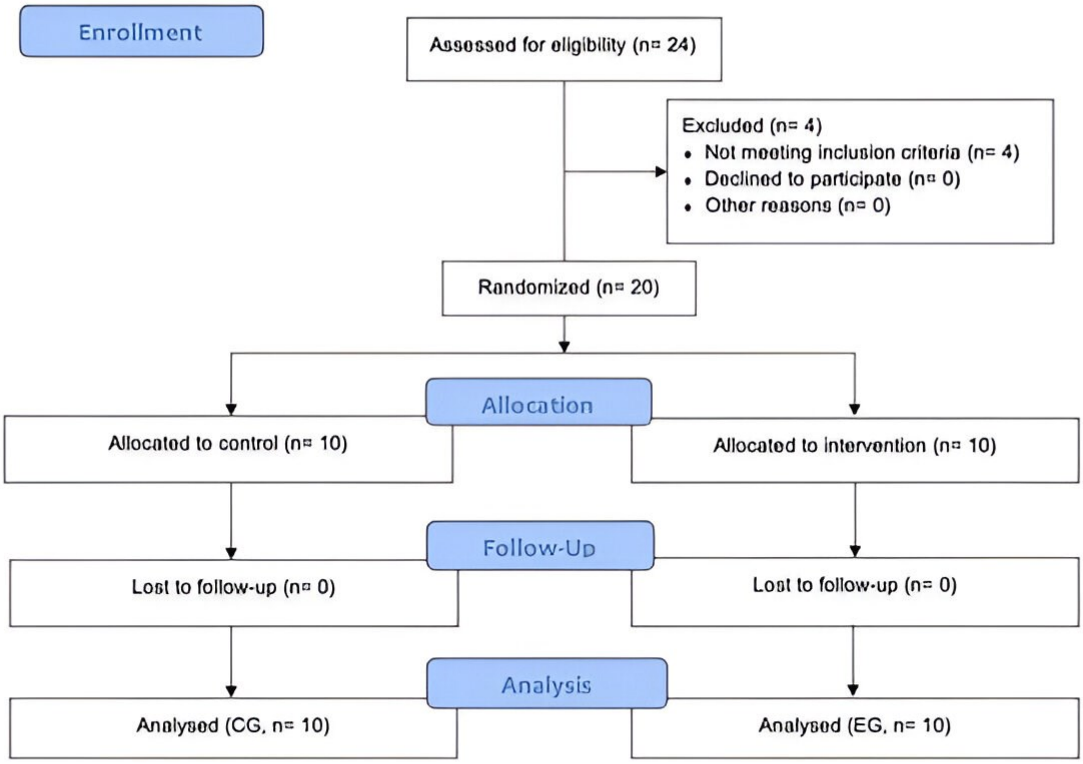


Figure 1. CONSORT diagram of participants' recruitment, allocation, follow-up and analysis.

Caption. CG: control group; EG: experimental group.

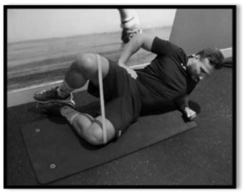
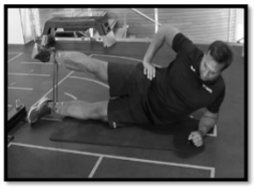
Procedures

A randomized controlled trial was executed which following the CONSORT 2010 Statement (Schulz, Altman, & Moher 2010) to analyze the impact of a 12-week low-load resistance training regimen on lower-limb injury incidence, and injury burden, and physical fitness attributes. Baseline and post-training intervention assessments encompassed vertical jumps (counter movement jump, CMJ; squat jump, SJ), change of direction ability (CODA, 505-CODA), linear sprints at 10, 20, and 40 m distances, repeated sprint ability (RSA, 5 × 30 m), and isometric strength exercises targeting the quadriceps, hamstrings, hip abductors, and hip adductor muscle groups in both dominant and non-dominant limbs. The baseline (pre) and post-intervention tests were performed on three different days during the same week. On the first day, the 505-CODA and linear sprints were performed. After 48 h (second day), the RSA test was performed. Finally, on the third day (48 h of rest), the isometric strength exercises in hamstring dominant (ISOHAMSd) and non-dominant (ISOHAMSnd), quadriceps dominant (ISOQUAd) and non-dominant (ISOHAMSnd), abductor dominant (ISOABDd) and non-dominant (ISOABDnd) and adductor dominant (ISOADDd) and non-dominant (ISOADDnd) limbs were performed. For jumping and speed tests, a warm-up lasting 10 min was performed using articular mobility exercises, progressive runs and sprints, and jumps. For the isometric strength tests, a specific 15-min warm-up was performed by executing the five exercises. While vertical jumping and isometric strength measurements were conducted in a controlled performance laboratory (18ºC, 60–70% relative humidity), assessments for 505-CODA, linear sprints, and RSA were carried out on an artificial grass field where the team typically conducted their training sessions, and players utilized their personal soccer boots. All evaluations occurred in the afternoon at 4-6 pm. Participants were instructed to consume their last meal three hours prior to the commencement of the tests, abstain from caffeinated beverages, and refrain from engaging in intense physical exercise. A certified strength and conditioning specialist supervised the testing procedures and provided verbal encouragement throughout all protocols (Raya-González, Torres Martin, Beato, Rodríguez-Fernández, & Sanchez-Sanchez, 2023). The intervention was focused on low-load resistance training and the strength sessions occurred on two non-consecutive days weekly (specifically, Tuesdays and Thursdays at 6 pm), lasting approximately 45-50 minutes. These sessions were scheduled after the regular on-field soccer training (Durán-Custodio, Castillo, Raya-González, & Yanci, 2023; Lovell, Siegler, Knox, Brennan, & Marshall, 2016; Marshall, Lovell, Knox, Brennan, & Siegler, 2015.).

Intervention program

The low-load resistance training program was based on a progression of five exercises as follows: A) Hip thrust with barbell, B) Bulgarian Split squat on TRX suspension, C) Clamshell with TheraBand, D) Tensor abduction, and E) Bulgarian Split squat on Bosu. Exercises A, B, and E were performed with free weights (barbell and dumbbells), and exercise C and D was performed with a tensioner (TheraBand). The exercises were performed as circuit training at an intensity between 40-50% of 1RM and 3 sets of each exercise, performing 15-20 repetitions and 90 s of recovery between sets, completing a total of 15 sets. In weeks 1-6 (W1-6) training was at an intensity of 40% of 1RM and 20 repetitions were performed; in weeks 7-12 (W7-12) at 50% of 1RM and 15 repetitions (Table 1). To calculate the 1RM, a submaximal and modified protocol was performed (O'Connor, Simmons, O'Shea 1989), which was used in a previous study (Durán-Custodio et al., 2023). To calculate the intensity of the exercises performed with elastic band, the TheraBand Manual was used as a reference and the yellow band resistance was used oriented to a low-load training intensity. In addition, it was based on the players' previous training records and previous research results (Andersen, Fimland, Cumming, Vraalsen, & Saeterbakken, 2018; Mascarin, De Lira, Vancini, Pochini, da Silva, & Andrade, 2017).

Table 1. Exercises, volume, intensity, and recovery time for the 12 weeks intervention training period.

Exercise	Temporal sequence of training program	Series	Repetitions	Rest between sets
Hip thrust 	W1-6: 40% 1RM W7-12: 50% 1RM	3	W1-6: 20 Rep. W7-12: 15 Rep.	90 s
Bulgarian split squat TRX 	W1-6: 40% 1RM W7-12: 50% 1RM	3	W1-6: 20 Rep. W7-12: 15 Rep.	90 s
Clamshell 	Yellow elastic band Yellow elastic band	3	W1-6: 20 Rep. W7-12: 15 Rep.	90 s
Tensor abduction 	Yellow elastic band Yellow elastic band	3	W1-6: 20 Rep. W7-12: 15 Rep.	90 s
Bulgarian Split Squat Bosu 	W1-6: 40% 1RM W7-12: 50% 1RM	3	W1-6: 20 Rep. W7-12: 15 Rep.	90 s

Caption. W: week; Rep.: repetitions; 1RM: one repetition maximum.

Measures

Injuries: The number, mechanism, type, body region, muscle structure, time, and duration of injuries were recorded. The data collection process adhered to the guidelines established by the Union of European Football Associations (UEFA) model criteria (Hägglund, Waldén, & Ekstrand, 2005). Subsequently, injury incidence (injuries / 1000 h exposure) and injury burden (days of absence / 1000 h exposure) were calculated (Bahr, Clarsen, & Ekstrand, 2018). Exposure duration was determined based on the cumulative time (in h) spent in training sessions and match-play. A player was considered fully rehabilitated post-injury when medical staff allow players to participate in training and competition.

Vertical jump performance: Players executed a bilateral CMJ, CMJ with the dominant (CMJd) and non-dominant (CMJnd) leg, and a bilateral SJ using the appropriate technique as previous studies (Impellizzeri, Rampinini, Maffiuletti, & Marcora, 2007). The determination of the dominant leg was based on individual soccer proficiency, specifically considering the preferred kicking leg (i.e., kicking leg) (Haddad, Abbes, Zarrouk, Aganovic, Hulweh, Moussa-Chamari, & Behm, 2023). Each participant made two attempts for each jump, with the best performance selected for subsequent analysis, and 1-min rest between attempts. Jump height (cm) was measured using a contact platform (Optojump Next, Microgate^{TM}, Bolzano, Italy), calculated as $h = gt^2/8$ (where h = height in cm, g = acceleration due to gravity 9.81 $m \cdot s^{-2}$, and t = flight time in seconds of the jump) (Bosco, Luhtanen, & Komi, 1983). The intraclass correlation coefficient (ICC) values for all tests performed in this study were obtained according to previous studies (Durán-Custodio et al., 2023)**.**

Change of direction ability (CODA): To assess CODA, players carried out the 505-CODA test as described in previous studies (Castillo, Raya-González, Scanlan, Sánchez-Díaz, Lozano, Yanci, 2021). Timing of the participants' performances was meticulously recorded using a photocell system (Polifemo, Microgate^{TM}, Bolzano, Italy) positioned over the first marker at 10 m. Each player undertook two attempts to execute the turn with each leg, distinguishing between the dominant (505-CODAd) and non-dominant (505-CODAnd) legs, and the best result was selected. Two min rest was set between attempts.

Linear test sprints: Players performed a 40 m linear sprint (Mendiguchia, Edouard, Samozino, Brughelli, Cross, Ross, Gill, & Morin, 2016), with splits at 10 (SPR10), 20 (SPR20), and 40 m (SPR40) distances. Three attempts were made, and the fastest time was selected, with 4 min rest between sprints. Four photoelectric cells (Polifemo, Microgate^{TM}, Bolzano, Italy) measured the sprint times.

Repeated Sprint Ability (RSA 5 x 30 m): The RSA test consisted of performing five consecutive sprints covering a distance of 30 m at maximal effort, with 25 s of recovery between each sprint (Spencer, Pyne, Santisteban, & Mujika, 2011). Sprint times were measured using two photoelectric cells (Polifemo, Microgate^{TM}, Bolzano, Italy) positioned at 0 m and 30 m distances. The total time for the five sprints (RSAtotal) was calculated.

Isometric Strength: Players engaged in isometric strength contractions lasting 5 s for the quadriceps, hamstrings, hip abductors, and hip adductors. A dynamometer (Carp Spirit Water Queen Digital Scale 50, BIODEX System Pro 4™, System 4 advance v.4.2, New York, USA), previously validated (Romero-Franco, Jiménez-Reyes, & Montaño-Munuera, 2017), was used for measured isometric strength (in kg). The measurement procedure for the tests ISOHAMSd, ISOHAMSnd, ISOQUAd, ISOQUAnd, ISOABDd, ISOABDnd, ISOADDd and ISOADDnd has been the same as in a previous study (Durán-Custodio et al., 2023). The imbalance between agonists and antagonists (Q–H imbalance and Abd–Add imbalance) were calculated using the formula: Imbalance (%) = (Agonist – Antagonist) x 100/ Agonist) (Newton, Gerber, Nimphius, & Shim, 2006).

Statistical analysis

Data are reported as mean ± standard deviations (SD). Normality of data distribution and homogeneity of variances were assessed using the Shapiro-Wilk test and Levene test, respectively. Injury incidence and burden are presented as the number per 1000 h of exposure and the number of absence days per 1000 h of exposure, each accompanied by 95% confidence intervals (CI). Rate ratios (RR) with 95% CI and Z-tests (Kirkwood, 2003) were computed to assess between-group differences (i.e., EG and CG) for injury incidence and burden. Parametric tests were used for all the variables analyzed and independent t-tests were employed to assess between-group differences at the pre-intervention stage. An analysis of covariance (ANCOVA) was conducted to identify potential training effects, with baseline values treated as covariates. Within-group pre-to-post differences were evaluated using paired-samples t-tests. Cohen's d effect size (ES) was calculated (Cohen, 1998) to assess practical significance, with results interpreted as small ($0.00 \leq d \leq 0.49$), moderate ($0.50 \leq d \leq 0.79$), and large ($d \geq 0.80$). Data analysis was conducted using the Statistical Package for the Social Sciences (SPSS™ Inc, version 27.0 for IOS, Chicago, IL, USA). The significance level for all analyses was set at $p < 0.05$.

Results

Five players sustained musculoskeletal injuries during the intervention period of the study, five in the CG (a total of 166 days of absence) representing 50% of the CG players (n = 10), and in the EG no player sustained injuries, during the 12-week intervention period. Of the total injuries in the intervention period, three occurred in W1-6 (in the CG) and two in W7-12 (in the CG). Differences in the injury profile are shown in Figure 2. Significant differences ($p<0.001$) were observed between the groups in terms of incidence (Figure 2A; CG: 9.57 vs. EG: 0.00 injuries/1000 h of exposure, RR = 0; 95% CI = 0). On the other side, significant differences ($p<0.001$) were also recorded in injury burden (Figure 2B; CG: 317.83 vs. EG: 0.00 days of absence/1000 h of exposure, RR = 0; 95% CI = 0).

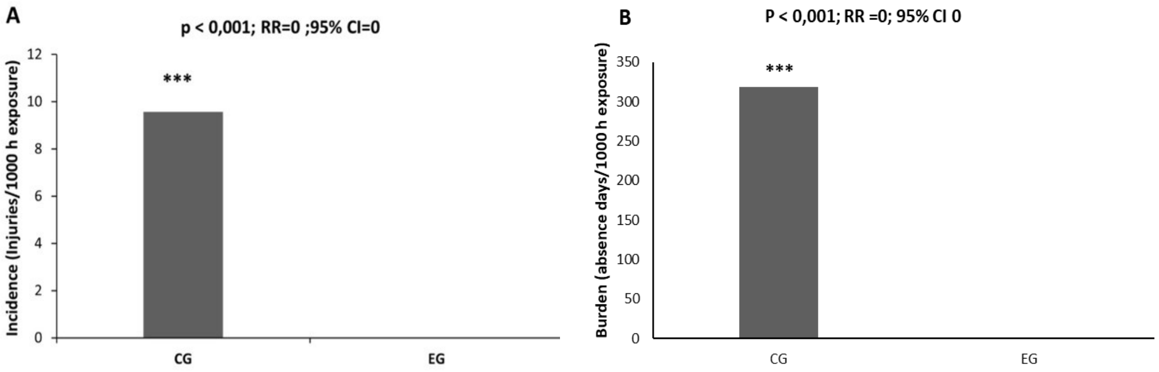


Figure 2. Between-groups differences in injury incidence (A) and burden (B).

Caption. CG: control group; EG: experimental group; RR: rate ratio; CI: confidence interval; *** Significant differences ($p < 0.001$)

The changes in physical fitness attributes after the 12-week low-load period intervention are displayed in Table 2. The ANCOVA model revealed between-group differences in all physical fitness variables in favour of the EG. Baseline to post-training values improved in all the physical fitness attributes ($p < 0.001$–0.024; ES = 3.58 to -7.80 large) in the EG. Otherwise, the CG only reported improvements in CMJ, ISOQUAd, ISOHAMSnd and ISOADDnd ($p < 0.002$-0.031; ES = -0.81 to -1.37, moderate). Furthermore, while in the EG a significant reduction in Q–H imbalance between baseline and post-training ($p < 0.001$; ES = 4.75 to 5.51, moderate) was observed, in the CG there was no significant change (p = 0.109–0.357; ES = 0.31 to 0.56, small). Finally, while in the CG the Abd–Add imbalance did not change between baseline and post-training (p = 0.129–0.519; ES = -0.21 to -0.53,moderate), in the EG there was a significant reduction (p = 0.005-0.008; ES = 1.06 to 1.15, large).

Table 2. Changes in physical fitness attributes after the 12-week low-load period intervention of control group (CG, n=10) and experimental group (EG, n=10).

	CG					EG					Between-group differences	
Variables	Baseline	Post	%Diff	p	ES	Baseline	Post	%Diff	p	ES	p	F
CMJ (cm)	35.81 ± 2.87	36.02 ± 2.94	0.58	0.031*	-0.81	37.39 ± 3.18	38.26 ± 3.06	2.27	<0.001***	-2.61	<0.001***	23.35
CMJd (cm)	20.12 ± 2.77	19.88 ± 2.55	-1.21	0.380	0.29	20.97 ± 1.87	21.56 ± 1.89	2.74	<0.001***	-1.71	<0.001***	23.35
CMJnd (cm)	20.51 ± 2.12	20.67 ± 2.33	0.77	0.636	-0.16	21.15 ± 1.62	21.65 ± 1.68	2.31	<0.001***	-1.77	<0.001***	0.93
SJ (cm)	27.80 ± 3.38	27.81 ± 3.49	0.04	0.928	-0.03	29.63 ± 3.38	30.25 ± 3.48	2.05	<0.001***	-2.01	0.002**	14.07
505-CODAd (s)	2.28 ± 0.11	2.28 ± 0.09	0.00	0.591	0.18	2.26 ± 0.07	2.18 ± 0.06	-3.67	<0.001***	3.07	<0.001***	64.88
505-CODAnd (s)	2.31 ± 0.04	2.30 ± 0.05	-0.43	0.253	0.39	2.31 ± 0.09	2.22 ± 0.08	-4.05	<0.001***	3.82	<0.001***	61.38
SPR10 (s)	1.71 ± 0.07	1.71 ± 0.06	0.00	0.664	0.14	1.74 ± 0.06	1.71 ± 0.06	-1.75	<0.001***	2.13	0.009**	8.56
SPR20 (s)	2.93 ± 0,10	2.93 ± 0.10	0.00	0.619	-0.16	2.98 ± 0.10	2.92 ± 0.09	-2.05	0.024*	0.86	0.029*	5.69
SPR40 (s)	5.23 ± 0.15	5.23 ± 0.14	0.00	0.801	0.08	5.30 ± 0.16	5.25 ± 0.16	-0.95	<0.001***	3.58	<0.001***	24.23
RSAtotal (s)	21.32 ± 0.76	21.30 ± 0.72	-0.09	0.584	0.18	21.30 ± 0.63	21.18 ± 0.57	-0.57	0.001**	1.46	0.008**	9.02
ISOQUAd (kg)	38.08 ± 4.34	38.39 ± 4.23	0.81	0.007**	-1.09	39.38 ± 2.95	40.60 ± 2.98	3.00	<0.001***	-4.16	<0.001***	49.88
ISOQUAnd (kg)	37.29 ± 5.49	37.48 ± 5.32	0.51	0.231	-0.41	36.88 ± 3.36	38.00 ± 3.35	2.95	<0.001***	-2.82	<0.001***	23.06
ISOHAMSd (kg)	21.05 ± 2.52	21.33 ± 2.58	1.31	0.043*	-0.74	21.72 ± 2.20	25.19 ± 2.20	13.78	<0.001***	-7.80	<0.001***	277.19
ISOHAMSnd (kg)	21.00 ± 3.31	21.35 ± 3.35	1.64	0.002**	-1.37	20.81 ± 2.40	24.72 ± 2.66	15.82	<0.001***	-6.93	<0.001***	329.41
Imb.Q-H Right (%)	44.70 ± 2.67	44.45 ± 2.74	-0.58	0.357	0.31	44.86 ± 3.45	37.91 ± 3.77	-18.35	<0.001***	4.75	<0.001***	149.03
Imb.Q-H Left (%)	43.74 ± 1.84	43.10 ± 2.42	-1.49	0.109	0.56	43.53 ± 4.48	34.88 ± 4.68	-24.77	<0.001***	5.51	<0.001***	160.30
ISOABDd (kg)	26.50 ± 4.73	27.18 ± 4.75	2.50	0.065	-0.66	29.71 ± 4.15	33.12 ± 4.05	10.30	<0.001***	-5.10	<0.001***	44.61
ISOABDnd (kg)	26.65 ± 4.38	27.21 ± 4.78	2.06	0.125	-0.54	29.09 ± 4.19	32.77 ± 4.08	11.23	<0.001***	-3.19	<0.001***	34.51
ISOADDd (kg)	23.07 ± 2.28	23.20 ± 2.22	0.56	0.258	-0.38	25.87 ± 2.32	29.67 ± 2.75	12.81	<0.001***	-4.21	<0.001***	92.50
ISOADDnd (kg)	23.55 ± 3.48	23.83 ± 3.49	1.17	0.015*	-0.95	26.67 ± 3.14	30.91 ± 3.09	13.72	<0.001***	-6.10	<0.001***	215.52
Imb.Abd-Add Right (%)	11.69 ± 8.72	13.42 ± 8.73	12.89	0.129	-0.53	12.20 ± 6.89	9.95 ± 6.16	-22.64	0.008**	1.06	0.005**	10.41
Imb.Abd-Add Left (%)	11.09 ± 7.46	11.74 ± 7.14	5.46	0.519	-0.21	7.72 ± 7.36	5.14 ± 7.60	-50.24	0.005**	1.15	0.012*	7.84

Caption. CMJ: counter movement jump; CMJd: dominant leg counter movement jump; CMJnd: non-dominant leg counter movement jump; SJ: squat jump; 505-CODAd: dominant leg change of direction ability; 505-CODAnd: non-dominant leg change of direction ability; SPR10: linear sprint in 10m; SPR20: linear sprint in 20m; SPR40: linear sprint in 40m; RSAtotal: repeated sprint ability total; RSAdec: repeated sprint ability fatigue index; ISOQUAd: dominant leg isometric strength in quadriceps muscles; ISOQUAnd: non-dominant leg isometric strength in quadriceps muscles; ISOHAMSd: isometric strength in hamstrings muscles in dominant leg; ISOHAMSnd: isometric strength in hamstrings muscles in non-dominant leg; Imb.Q-H Right: Imbalance quadriceps-hamstrings in right leg; Imb.Q-H Left: Imbalance quadriceps-hamstrings in left leg; ISOABDd: isometric strength in abductors muscles in dominant leg; ISOABDnd: isometric strength in abductors muscles in non-dominant leg; ISOADDd: isometric strength in adductors muscles in dominant leg; ISOADDnd: isometric strength in adductors muscles in non-dominant leg; Imb.Abd-Add Right: Imbalance abductors-adductors in right leg; Imb.Abd-Add Left: Imbalance abductors-adductors in left leg; %Diff: difference in percentage between groups; p = level of significance; ES: Effect size. *p < 0.05, **p < 0.01 *** p < 0.001: significant differences between baseline and post or between groups.

Discussion

The aim of this study was to assess the impact of a 12-week low-load resistance training regimen on injury incidence, injury burden, and physical fitness attributes in young semiprofessional soccer players. Several studies have investigated the efficacy of strength training programs based on training intensities of 70-80% of maximal effort to reduce injury incidence in soccer players (Beato, Maroto-Izquierdo, Turner, & Bishop, 2021). Given the scarcity of empirical data on the effects of low-load resistance training in injury prevention, this pioneering study sought to explore the dual facets of performance enhancement resulting from such lower load resistance training. The main findings revealed a reduction in injury incidence, and injury burden in players who participated in a low-load resistance training program (i.e., EG). Additionally, the EG exhibited more pronounced enhancements across all fitness attributes, including vertical jump, 505-CODA, linear sprints, RSA, and isometric strength, in comparison to the CG. In addition, the EG showed significant reductions in both Q-H imbalance and Abd-Add imbalance, whereas no significant alterations in these variables were observed in the CG. These outcomes collectively suggest that the low-load resistance training program proved efficacious in mitigating injuries (both incidence and burden) while concurrently enhancing physical fitness.

According to previous studies, the application of low-load resistance training programs has already demonstrated the reduction of the number of injuries in young semiprofessional soccer players (Olivares-Jabalera et al., 2021; Pérez-Gómez et al., 2022) and the improvement of physical fitness (Gaamouri, Hammami, Cherni, Oranchuk, Bragazzi, Knechtle, Chelly, & van den Tillaar, 2023; Lopes, Machado, Micheletti, de Almeida, Cavina, & Pastre, 2019). However, few investigations have analyzed the effect of low-load resistance training on the injury incidence and burden of soccer players (Iodice et al., 2020). These findings could be explained by the adaptation caused by the prescribed exercises during the intervention period, particularly on hip abductors such as the gluteus medius, which is crucial for specific soccer tasks like jumps and changes of direction (Heick, Talkington, & Jain, 2020). A recent study evaluated the Q-H imbalance, observing that legs with a lower Q:H ratio presented a decrease in concentric and eccentric hamstring strength ($p < 0.01$; moderate and large ES) (Fritsch, Dornelles, Oliveira, & Baroni, 2023). The authors concluded that hamstring strength deficit is a key factor for low Q-H ratios in male soccer players. These results align with previous studies that have shown that improvement of Q-H imbalance can be a positive factor in the prevention of lower extremity musculoskeletal injuries and in the improvement of decompensations in the pelvis (Croisier, Ganteaume, Binet, Genty, & Ferret, 2008). On this basis, in our study significant reductions in EG were found in both Imb.Q-H Right and Imb.Q-H Left ($p < 0.001$; ES = 4.75 - 5.51), however, there was no reductions in CG. Another important factor to consider is the possible Abd-Add muscle imbalance of both legs. In a recent study, hip abductor and adductor strength and to what extent these factors are related to dynamic postural balance and knee and ankle mobility in young elite female basketball players were studied (Domínguez-Navarro, Benitez-Martínez, Ricart-Luna, Cotolí-Suárez, Blasco-Igual, & Casaña-Granell, 2022). In our study, significant reductions were observed in Abd-Add right and left imbalance ($p < 0.005 - 0.008$; ES= 1.06 - 1.15), while no improvements were observed in CG. Therefore, the potential role of abductors and adductors in hip strength could help improve hip-knee-ankle axis imbalances and aid in injury prevention processes.

It should be noted that the six strength exercises performed in this study (i.e., hip thrust with barbell, Bulgarian Split squat on TRX suspension, clamshell with TheraBand, Tensor abduction, and Bulgarian Split squat on Bosu) were largely focused on working and activating the gluteus medius, gluteus maximus, and hamstrings. Previous studies have shown that one of the biomechanical injury risk factors includes inadequate strength and muscle control of the hip stabilizers (Bakal et al., 2024; Ribic et al., 2024). In this context, research has highlighted the importance of lumbo-pelvic muscle function in the prevention and treatment of hamstring injuries, showing a high correlation between gluteus medius activation and strength during running and the incidence of hamstring injuries (Franettovich et al., 2017). The exercises proposed in the training program of this study aimed to improve the strength of these hip-related muscle groups, which may have positively impacted the reduction of injury incidence and burden. This conclusion is supported by the observed reduction in Q-H imbalance and Abd-Add imbalance in the EG. These findings suggest that better balance and coordination between agonist and antagonist muscles of the hip and knee in young semiprofessional soccer players, achieved by low-load resistance training, may be one of the causes of reduced injury incidence and burden. Furthermore, previous studies have shown that strengthening the hip musculature helps reduce the knee valgus angle by up to 60%, which could help prevent major knee injuries, such as patellofemoral pain syndrome or anterior cruciate ligament injuries (Emamvirdi, Letafatkar, & Khaleghi Tazji, 2019).

Strength programs applied to soccer players aim not only to prevent and reduce injuries but also to improve the players' physical performance. Previous studies have combined traditional resistance training at high loads (i.e., 80-90% 1RM) with training at lower loads (i.e., ~40% 1RM). Surprisingly, both paradigms produced comparable improvements in body composition and certain neuromuscular performance metrics, despite substantial differences in external load lifted (Mitchell, Churchward-Venne, West, Burd, Breen, Baker, & Phillips, 2012; Morton, Oikaw, Wavell, Mazara, Mcglory, Quadrilatero, Baechler, Baker, & Phillips, 2016). It is important to note that lower loads with higher absolute volumes have been shown to elicit sustained sarcoplasmic protein synthesis 24 h after exercise (Burd, West, Staples, Atherton, Baker J, Moore, Holwerda, Parise, Rennie, Baker S, & Phillips, 2010). This finding suggests that training at lower loads can increase protein synthesis across various muscle fractions (Lim, Kim H, Morton, Harris, Phillips, Jeong, & Kim C, 2019) and potentially lead to increased oxidative capacity (Burd et al., 2010; Schoenfeld, Peterson, Ogborn, Contreras, & Sonmez, 2015). In conclusion, low-load resistance training could be positive for improving the performance of young semiprofessional soccer players. The results of the present study show that EG players improve all physical attributes (i.e., vertical jump performance, 505-CODA, linear sprint test, Repeated Sprint Ability (RSA), and isometric strength). These findings align with those reported in previous studies following the implementation of distinct low-load resistance training programs (Iodice et al., 2020; Lesinski et al., 2021).

Our study corroborates the outcomes obtained by (Iodice et al., 2020) where significant enhancements were observed in extensor and flexor leg muscle strength, as well as CMJ performance among elite senior futsal players. These improvements were noted during an experimental 8-week protocol at 50% of 1RM (Iodice et al., 2020). In another study involving 36 young elite female soccer players (17 ± 1 year), strength exercises at moderate intensity (40-50% of 1R; 20-40 repetitions) led to significantly better performance was shown for T-test and Bourban's ventral test (d = 1.28-2.28; p = 0.000-0.001). Additionally, significant performances were also found for COD and 10- and 20-m linear sprints (d = 0.85-1.44; p = 0.000-0.026) (Lesinski et al., 2021). Based on the results obtained in the present study and in previous studies (Franettovich et al., 2017; Lesinski et al., 2021), it has been observed that low-load resistance training can improve injury incidence and burden in addition to improving fitness in young semiprofessional soccer players. On the other hand, low-load resistance training is presumed to induce less exercise-induced muscle damage due to its lower intensity (Lim et al., 2019; Schoenfeld et al., 2015), and therefore could help reduce the risk of injury (Olivares-Jabalera et al., 2021; Pérez-Gómez et al., 2022). Therefore, the low-load resistance training method could be a suitable option at certain times of the season for strength training in soccer.

This study is not exempt of limitations being the first one that only 20 young semiprofessional male soccer players belonged to a unique team participated in the study, so the generalizability could be limited, however, we consider the high ecological validity. Additionally, despite EG performed additional strength training without reducing the regular soccer training, we are not able to ensure the overall training load between both groups (CG and EG) because the training load has not been quantified. Finally, it would be interesting to record the injury incidence and absence days after an injury over time to understand whether the strength training program has chronic adaptations.

Conclusions

The implementation of a 12-week low-load strength training program, organized in a circuit training at an intensity between 40-50% of 1RM and 3 sets of each exercise, performing 15-20 repetitions and 90 s of recovery between sets, completing a total of 15 sets, primarily targeting the hip abductor, hamstring and quadriceps muscle as part of routine soccer training, has shown a decrease in both injury incidence and injury burden. Furthermore, this resistance training method has led to improvements in physical fitness attributes, including jumping ability, CODA, sprinting, RSA, and isometric strength. Moreover, low-load strength training could aid to reduce Q-H and Abd-Add imbalances. Overall, these findings collectively suggest that the low-load resistance training program was effective in reducing injuries (both incidence and burden) while simultaneously enhancing physical fitness. Ultimately, we advocate for further exploration in this intriguing area of study, employing similar interventions to deepen and refine our understanding of this crucial aspect related to musculotendinous injuries in soccer.

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